SPECIAL REPORT

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Ecosystem health and veterinary medicine

N. Ole Nielsen

Introduction

Presently, society seems ill-equipped with the appropriate knowledge, institutions, ethics, and professional expertise to address human induced degradation of the environment. The health paradigm has served to improve the well-being of humans and their animals. Why not extend it to the environment? From both theoretical and practical perspectives, adaptation of the health paradigm to the environment is attractive. The idea is not new; the concept has been explored formally over the last ten years, especially by Rapport (1–4) and Schaeffer (5,6). Its utility appears to have been recognized by a number of scientists, agencies, and the authors of Canada's "Green Plan" (7).

Application of the health paradigm to the environment immediately suggests an array of approaches and mechanisms that have proven successful in promoting human, animal, and plant health. It also provides a logical framework in which veterinary medicine's interest in wildlife, toxicology, and epidemiology can be more effective.

Defining health

The health paradigm incorporates both objective and subjective components. The World Health Organization (WHO) has defined health as follows;

> "Health is the extent to which an individual or group is able, on the one hand, to realize aspirations and satisfy needs and, on the other hand, to change or cope with the environment. Health is therefore seen as a resource for everyday life, not the objective of living; it is a positive concept emphasizing social and personal resources, as well as physical capacity."

Extension of the concept of health to the environment must also include subjective and value-laden components if it is to be useful in guiding human affairs. Indeed, it is the socioeconomic and ethical dimensions of the health model that suit it for application to the environment. A purely biomedical model of health would be inadequate. Environmental decisions require judgements that take into account biophysical, ethical, socioeconomic, and aesthetic considerations. Also, the health paradigm offers useful models to develop more effective institutional structures, strategies, and ways of thinking to assure the health of the environment and its constituent ecosystems. This is perhaps the most attractive or compelling reason to utilize this approach, rather than close analogies of human/animal disease to those of ecosystems.

For purposes of assessing the notion of applying the health paradigm to the environment, the WHO definition might be paraphrased as follows:

> "Environmental health is the extent to which a given ecosystem and its component parts are able to support human activities on the one hand, and to sustain populations of all organisms, on the other. Environmental health, therefore is the ability of an ecosystem to cope with human-induced change; it is not the sole objective of conservation, but a concept emphasizing balance among social, ethical, aesthetic and biological goals."

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In applying the health paradigm to ecosystems, allowance must be made for the differences in temporal and spatial scales and complexity. As a consequence, some prefer the concept of ecosystem "integrity". Integrity implies the ability of an ecosystem to be self-regulating (or organizing), in the face of internal or external stresses; dynamically stable; and evolving toward increasing complexity and integration (8). Healthy ecosystems have integrity.

While the concept of ecosystem health has taken root in some quarters of the environmental community, there is very little acknowledgement of the specific idea within agricultural circles. Here the idea of "sustainability" has been the subject of more formal attention. Because it is reasonable to equate sustainability with health, some of the difficulty being experienced in making "sustainable development" and "sustainable agriculture" operational concepts may be overcome or eased by a conscious effort to apply the health paradigm to these domains.

Dean, Ontario Veterinary College, University of Guelph, Guelph, Ontario N1G 2W1.

Veterinary medicine can contribute to achieving ecosystem health and sustainability by:

— interpreting or translating the health paradigm into useable ecosystem-related principles of use in environmental science;
— monitoring the health of both domestic and wild animals as useful indicators of ecosystem health;
— applying epidemiological methods to the management of ecosystem health;
— assuring the rational application of toxicology data to environmental issues;
— providing professionals with specialized training in ecosystem health.

These subjects are discussed in the following passages:

Ecosystems and the health paradigm

The animal organism is a complex system which integrates a wide variety of organs and tissues. Similarly an ecosystem consists of distinct biological entities which interact with each other and the inanimate environment to form a relatively stable unit.

Ecology, including the study of ecosystems, is a very young science (8). Indeed there are some who dispute the belief that the study of ecosystems is legitimate science. Surely to the extent that medicine is a legitimate science, so is the study of ecosystems. Kay (8) has suggested that ecology is at a stage of development corresponding to the study of physics in Galileo's time. Therefore, it is not surprising if the present methods of analysis of ecosystems lack rigor and sophistication.

Patients and populations in comparison to ecologic units and ecosystems

Health care systems deal with 1) individuals (patients), who are the basic unit of concern; and 2) populations categorized by some common relationship or function, for example, family, community, region, occupation, sex, age, species, etc. In ecosystem health, the ecological equivalent of a patient is proposed to be the "eco-unit", which is defined as being a significant portion of an ecosystem managed as an entity, such as a farm, woodlot, park, etc. Various eco-units can be aggregated into larger more biologically and geographically defined ecosystems for analysis and management, in the same way that the health of groups of individuals is monitored and managed as part of a public health system.

Organizations presently concerned with ecosystem health are closer to population medicine than to patient oriented medicine. For example, Environment Canada's State of the Environment Reporting Directorate is developing its reporting system on a hierarchy of large ecologic or ecosystemic management zones, and is not focusing on eco-units.

Eco-unit medicine or clinical ecology

Patient-oriented medicine by its very nature is empirical and, classically, has combined art and science. Even in poorly understood diseases it is possible to give reasonably accurate diagnoses, to prescribe effective treatments, to make accurate prognoses, to recommend effective preventive measures, and to give due regard to socioeconomic and ethical circumstances. Similarly the beneficial practice of eco-unit medicine is not dependent on the complete scientific understanding of function or impairment in a given eco-unit and requires integration of socioeconomic and ethical circumstances.

To achieve progress in understanding health and disease in the environment, scientists and practitioners must employ astute observation and careful analysis of field experience (clinical research) in addressing problems. This experience must be shared and evaluated in appropriate peer review journals. Presently, many environmental studies are published as government reports and not subject to peer review. Environmental agencies waste manpower and funds on medialed issues.

The practice of eco-unit and ecosystem medicine, or clinical ecology, has not yet evolved a systematic methodology that begins to compare to that of traditional medicine. This awaits much more research to describe the structure, physiology, pathology, and potential remediation of eco-units and ecosystems.

It can be anticipated that there are two kinds of indicators of eco-unit disease or degradation; those which are a general response to stress, and those which are characteristic of a specific agent. In either case, animal disease can be such an indicator. At present, the establishment of a robust taxonomy of eco-unit and ecosystem ills awaits development.

The counterpart of general medicine in ecosystem health is based on evaluation of major environmental components, namely soil, water, atmosphere, plants, animals, and microbes, and their interaction in phenomena like nutrient cycling, primary productivity, species diversity, energy flows, regressive changes, etc. The application of Selye's concept of stress to the environment by Rapport et al. (2) represents the most ambitious attempt to formulate general principles of ecosystem response to perturbation. It appears to have been widely adopted as a general notion, but not as a specific methodology (not unlike human and animal medicine). The term stress has found wide currency as a descriptor for a variety of potential causes of environmental degradation. There is a modest literature describing indicators or signs of stress in ecosystems (2). It has also been possible to define a general ecosystem distress syndrome (1).

Animals as monitors of ecosystem health

One of the important indicators of the health or integrity of an ecosystem and its components is the health of indigenous wild or domestic animals. Therefore, the veterinarian can make important contributions to procedures established to manage ecosystem health. Under these circumstances, veterinarians must not only assess disease in the interest of the animal per se, but also in the context of the ecosystem of which it is part. From this perspective veterinarians with an interest in wildlife diseases will surely enhance their contribution to society.

Since domestic animals are near the top of many food chains and are confined to one location, they can serve as extremely useful monitors of the environment in which they live. Existing veterinary infrastructure provides the means to capitalize on this potential. So

far, this group of animals is virtually unused as a regular monitor in formal programs designed to assess the health of ecosystems or their component parts (8). It should not be difficult to redress this circumstance.

Sustainable agriculture, farming systems and epidemiology

The goals of sustainable agriculture are to maintain indefinitely natural resources and productivity (health); minimize adverse environmental impact; optimize production with minimal external inputs; provide adequate economic returns to farmers; satisfy human needs for food; provide for the social needs of farm families, workers, and communities; and promote aesthetically and ethically acceptable farming practices (9,10). The integration of these goals requires an ecosystems approach. Hart and Sands (11) have provided a good systems framework (Figure 1) which relates the farm to both socioeconomic and the biophysical dimensions. Such a model can be applied to any eco-unit.

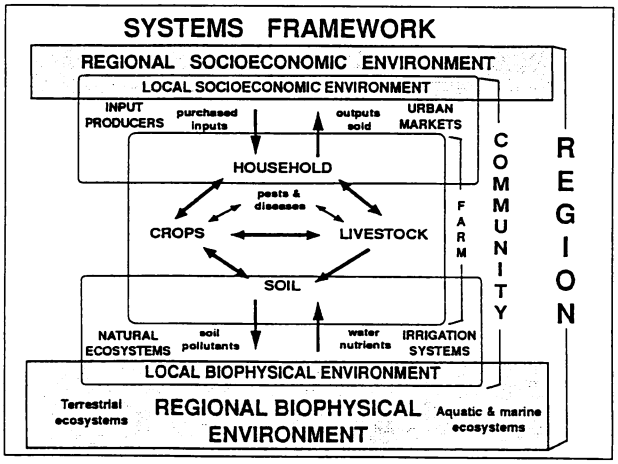

Figure 1. Figure 1. A systems framework for a farm eco-unit (11).

Research and analysis of farming ecosystems have received little attention in Canada. The academic and research establishment in agriculture is structured along disciplinary or commodity lines, with the result that the ecosystems approach is relatively neglected. Presently no one is an expert in farming besides the farmer.

Epidemiological principles can be applied to the health management of any eco-unit or ecosystem. Because sustainability and health are close to being synonymous, institutions and systems established to manage and maintain the health of eco-units and ecosystems, if successful, would by definition help to achieve sustainability. The case of agriculture may be of particular interest because veterinary medicine is in a good position to contribute to making sustainability an operational concept in this sphere.

Veterinarians have pioneered the practice of animal health management. Livestock herds are monitored regularly by standard measures of health and productivity. These data are recorded and analyzed by computer, with reference to established indices and goals, and serve as the basis for health management. This approach begins to come close to the type of management that must be extended to the whole farm enterprise or any other eco-unit if ecosystem health and sustainability are to be promoted at the farm level. The ability to do this depends on characterizing the parameters of eco-unit health that are amenable to regular monitoring and meaningful analysis. Research to establish such parameters must receive high priority. For example, techniques for monitoring nutrient flows, such as nitrogen cycling, on the farm would be useful. Comparable management techniques could be developed for any discrete portion of the environment.

Veterinary epidemiological expertise can be useful in the development of increased competence in farming systems research and practice. Since Canadian veterinary epidemiology is relatively well developed, if not *avant garde*, by world standard, agricultural agencies who wish to apply the health paradigm to developing sustainable agriculture can use their veterinary arms to provide "in-house" expertise.

Powerful information technology which has been essential to progress in epidemiology, and can also provide agriculture and environmental science with necessary tools to undertake ecosystem health monitoring and management. Without this technology, it is doubtful that practices to assure ecosystem health (sustainability) could become a reality. Manipulation and analysis of large amounts of data collected in the monitoring process will be increasingly important as farming systems management evolves.

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Toxicology

Concerns for ecosystem health are currently dominated by issues pertaining to chemicals and toxicology. Rapid advances in analytical methodology and the vast numbers of toxicants (in comparison to other causes of disease) underlie this situation (12). While this domain is very important, it is only one of several fundamental causes of ecosystem degradation and must be kept in perspective.

There is a dearth of professionals in environmental management trained to really understand the implications of chemicals in disease processes. As a consequence, the interpretation of measurements of chemicals in nature can lead to exaggerated responses and misplaced priorities. While the detection of chemicals *per se* is important, it is equally essential to assure a full appreciation of their role in disease processes. Because veterinarians are educated to solve animal

health problems, those who focus on the area of toxicology are particularly well suited to assess the role of chemicals in causing environmental degradation signalled by effects in animals.

Veterinarians and the need for an ecosystem health professional

The foundation of a patient oriented health care system is the professional who is trained as a generalist to solve problems and to promote health. Typically, this person sets health goals, defines problems, makes diagnoses, prescribes therapy, or refers the problem to a specialist. In ecosystem health there is the same need for a generalist to solve or refer problems to specialists and to help managers promote the health of eco-units for which they are responsible. Presently none exists. Undergraduate environmental science and study programs vary widely and there are no generally accepted guidelines or standards for such programs (13).

The establishment of specific programs for educating ecosystem health generalists or "physicians to the environment" seems essential. An ecosystem health generalist would be expected to have an education that encompasses general natural sciences, relevant social sciences, the humanities, sufficient medical training to understand disease, a thorough grounding in ecology, appropriate subject matter in environmental sciences, and "clinical" training in ecosystem health problem solving. It would probably take about six years to educate such individuals — four years in an undergraduate program and a further two years in a problem based graduate degree program that might be akin to some MBA programs.

In the future, one can expect that veterinary students with an interest in wildlife diseases, toxicology, or epidemiology will adapt their educational objectives to emulate such a program, especially as they obtain more discretion over their own education.

It is envisaged that veterinarians, agrologists, environmental science students, engineers, etc., or others who wish to become expert in ecosystem health management, or applied sustainable agriculture, will tailor their undergraduate programs in this direction and complete their education in a two year ecosystem health graduate program that focuses on solving on-farm problems related to ecosystem health.

It will also be essential to develop the means to teach environmental problem solving. This can be done by the establishment of "environmental problem clinics" at appropriate universities. These would meet a practical need for service to the community, but more importantly could serve as 1) a problem-based training ground for students who wish to become ecosystems health generalists, and 2) a conduit for "clinical" material for research.

Conclusion

The health paradigm offers society a powerful approach to address concerns about environmental degradation. Veterinarians can play a significant role in making this potential a reality, especially in relation to agriculture and its quest for sustainability.

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